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Studies on the biology of Collembola*

BY

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The life history of three species i.e. *Onychiurus bhattii* Yosii, *Seira iricolor* Yosii *et* Ashraf and *Sminthurinus mime* Börner, has been studied. The Collembola lay eggs singly or in clusters and continue to moult throughout the life even after sexual maturity. The sexes are quite similar and difficult to distinguish. Soil type and soil pH has great influence on oviposition. The Collembola feed upon a variety of foods. *Cyphoderodes punjabicus* Yosii *et* Ashraf was recorded as termitophilous, feeding upon the regurgitated food of termites. Arachnids, Dermaptera and Coleoptera are the natural enemies of these Collembola.

INTRODUCTION

No observation on the biology of the Collembola has previously been made in Pakistan. Elsewhere the life histories of certain species of some economic importance have been observed. RIPPER (1930) mentions that in the case of *Hypogastrura manubrialis* Tullberg, sexual maturity is attained in 5 - 7 weeks and the total life span is 5 - 10 months. In *Sminthurus viridis* Linn. (MACLAGAN 1932 — in England), there are 7 nymphal instars and the total duration of the life-cycle from ovum to imago is approximately 2 1/2 months. BRITT (1951) in United States studied the life history of *Achorutes armatus* Nicolet and found that it takes 23 - 27 days to complete the life-cycle. Under laboratory conditions he mentions the possibility of 12 or more generations in a year.

During the present investigations, the life history of three local species i.e. *Onychiurus bhattii* Yosii, *Seira iricolor* Yosii *et* Ashraf and *Sminthurinus mime* Börner has been studied.

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METHODS

It is not easy to rear these small and delicate insects in captivity. Small wide mouth glass jars with wire gauze screw caps were employed. Three parts of finely ground and sterilized soil with one part of leaf manure were placed in the jars. Freshly fallen leaves of *Trifolium* and *Sesbania aegyptica* were provided as food. Sufficient moisture, which is an essential requirement, was provided. The experiments were conducted during the months of January, February, and March, at room temperature varying from 13.6° C-27° C. Under these conditions the insects lived quite actively and breeding took place in almost all the jars. In the case of black coloured species *(S. mime)* a little plaster of Paris was mixed with the soil to make the specimens readily visible.

On account of the small size of living spaces in the soil, it is difficult to observe moulting; however, a very careful watch was kept. The head width of the specimens was noted just after moulting. For calculating the number of instars Dyar's law was applied, which proved quite useful.

OBSERVATIONS ON LIFE HISTORY

The Collembola have no metamorphosis (a-metamorphic). The newly hatched young ones have the same general appearance as the adults.

The sexes are quite similar and difficult to distinguish. When the abdomen of the female is filled with eggs, it is bigger in size than the male and can be separated.

In spite of prolonged observations, no mating was observed. Considerable data concerning sperm transfer in Collembola are available. Quoting from Christiansen (1964), « it is clear at the present time that most, and probably all, Collembola accomplish fertilization by a sperm packet transfer mechanism (Sharma & Kevan, 1963 ; Schaller, 1952, 1953, 1954). In an extensive study, Mayer (1957) developed a classification illustrative of the different types of processes to be found : (a) simple sperm drop produced independent of the presence of other individuals and without direction *(Onychiuridae)* ; (b) stalked droplet produced as above but with the possibility of an increased rate of deposition in the presence of a mate *(Orchesella, Tomocerus, Entomobrya)*; (c) stalked droplet produced in an undirected fashion but requiring the presence of a suitable female *(Dicyrtoma* and *Allacma)* ; (d) single droplet but with deposition and pick-up closely controlled *(Sminthurides aquaticus)* (Bourlet) and *Podura aquatica* (Linnaeus) ». In the present studies, even in *Sminthurids*, copulation could not be observed.

The Collembola, unlike other insects, continue to moult throughout life, even after sexual maturity. They may have an indefinite number of instars depending upon the length of life and available food. According to Britt (1951) an individual of *Achorutes armatus* moults 24 times during its life of 118 days. As mentioned by Christiansen (1964), « the number of moults required for sexual maturity varies from three to twelve but a considerable majority require 4 - 6 moults (Lindenmann, 1950, Uchida and Hongo, 1962 ; Milne, 1962 ; Marshall and Kevan, 1962, and Sharma and Kevan, 1963) ».

It has been observed that in all cases the eggs were usually laid in the crevices of the soil and under the plant food material in the culture jars.

1. **Onychiurus bhattii** Yosii, 1963.

Eggs.

The eggs of *O. bhattii* are spherical, smooth, white and may be laid singly or in clusters. The maximum number in a cluster was found to be 16. The average size of an egg is 0.218 mm. in diameter. Under laboratory conditions the egg stage is six days.

Instars.

The insect passes through four nymphal instars before sexual maturity. Head widths of young from first instar to adult were measured and are represented in the following table:

TABLE I

Instars and Head width

Number of Instars	Head width in mm	Head width as calculated according to Dyar's law
I	0.109	—
II	0.145	0.109 × 1.4 = 0.152
III	0.20	0.152 × 1.4 = 0.212
IV	0.290	0.212 × 1.4 = 0.296
Adult	0.363	0.296 × 1.4 = 0.414

TABLE II

Duration of the Stadia

Instars	Time in days	Head width in mm	Proportion of Head width to body length	Length of Antenna in mm
I	6	0.109	1 : 4.3	0.09
II	4	0.145	1 : 4.5	0.10
III	5	0.20	1 : 4.5	0.18
IV	6	0.290	1 : 5	0.23
Adult	71	0.363	1 : 5	0.33

In the first instar, the average head width is 0.109 mm. The proportion of head width to body length is 1 : 4.3 and the length of the antenna is 0.09 mm. The duration of the stage is six days.

In the second instar the average head width is 0.145 mm, the proportion of head width to the body length is 1 : 4.5, and the length of the antenna is 0.10 mm. This stage lasts for 4 days.

In the third instar the average head width is 0.20 mm, the proportion of head width to body length is 1 : 4.5 and the length of the antenna is 0.18 mm. This stage lasts for five days.

In the fourth instar the average head width is 0.29 mm. The proportion of head width to the body length is 1 : 5, and the length of the antenna is 0.23 mm. The duration of this instar is six days.

After passing through four nymphal instars, the insects become sexually mature and continue to grow and moult until they reach the maximum size of 1.5 - 2.5 mm. The maximum head width of an adult is 0.363 mm. Under laboratory conditions the total length of life, on an average, is 71 days. One individual moulted 15 times during his life of 73 days. It was observed that generally 26 - 30 days are required for a complete life-cycle. In the laboratory, it should be possible to have 10 - 12 generations in a year.

2. **Seira iricolor** YOSII et ASHRAF, 1964.

Eggs.

Eggs of this species are spherical, smooth, white and are not laid in clusters. The average diameter of an egg is 0.2 mm. The egg stage ranges 5 - 8 days.

Instars.

This species undergoes 3 nymphal moults before attaining sexual maturity. Head width of individuals measured from the first instar to the adult are as under:

TABLE III

Instars and Head width

Number of Instars	Head width in mm	Head width as calculated according to Dyar's law
I	0.145	—
II	0.218	0.145 × 1.4 = 0.203
III	0.290	0.203 × 1.4 = 0.284
Adult	0.363	0.284 × 1.4 = 0.397

TABLE IV

Duration of the Stadia

Instars	Time in days	Head width in mm	Proportion of Head width to body length	Length of Antenna in mm
I	5	0.145	1 : 3.75	0.181
II	8	0.218	1 : 5.33	0.49
III	10	0.290	1 : 6.12	0.76
Adult	63-70	0.363	1 : 7	0.87

In the first instar the average head width is 0.145 mm. The proportion of head width to body length is 1 : 3.75 and the length of the antenna is 0.181 mm. The duration of this instar is five days.

In the second instar the average head width is 0.218 mm, the proportion of head width to body length is 1 : 5.33 and the length of the antenna is 0.49 mm. This stage takes 8 days for its completion.

In the third instar the average head width is 0.290 mm, the proportion of head width to body length is 1 : 1. 12 and the length of the antenna is 0.76 mm. The insect remains for 10 days in this instar.

After three instars the insect reaches sexual maturity but growth continues until the maximum size of 2.6 mm is attained. The maximum head width of an adult is 0.363 mm. Total life of an individual ranges from 63 - 70 days. It takes 28 - 35 days for completion of the life-cycle.

3. **Sminthurinus mime** BÖRNER, 1907.

Eggs.

The eggs of this species are also spherical, like those of *O. bhattii* and *S. iricolor,* but are slightly larger. The average diameter is 0.25 mm. The eggs may be laid singly or in clusters. Maximum number in a cluster is 12. The egg stage is 7 - 10 days.

Instars.

This species passes through 5 nymphal instars before it reaches sexual maturity. Head widths measured from first instar to adult stage are as under:

TABLE V

Instars and Head width

Number of Instars	Head width in mm	Head width as calculated according to Dyar's law
I	0.109	—
II	0.145	0.109 × 1.4 = 0.152
III	0.20	0.152 × 1.4 = 0.212
IV	0.290	0.212 × 1.4 = 0.296
V	0.381	0.296 × 1.4 = 0.414
Adult	0.43	0.414 × 1.4 = 0.579

In the first instar the average head width is 0.109 mm. The proportion of head width to body length is 1 : 3 and the length of the antenna is 0.145 mm. The insect remains for 4 days in this stage.

In the second instar the average head width is 0.145 mm, the proportion of head width to body length is 1 : 3.2 and the length of the antenna is 0.181 mm. This stage takes 7 days.

TABLE VI

Duration of the Stadia

Instars	Time in days	Head width in mm	Proportion of Head width to body length	Length of Antenna in mm
I	4	0.109	1 : 3	0.145
II	7	0.145	1 : 3.2	0.181
III	8	0.20	1 : 3	0.20
IV	10	0.290	1 : 3	0.29
V	13	0.381	1 : 3.8	0.43
Adult	75-87	0.43	1 : 3.8	0.52

In the third instar the average head width is 0.20 mm, the proportion of head width to body length is 1 : 3 and the length of the antenna is 0.20 mm. This stage takes 8 days.

In the fourth instar the average head width is 0.290 mm, the proportion of head width to body length is 1 : 3, and the length of the antenna is 0.29 mm. This stage takes 10 days for its completion.

In the fifth instar the average head width is 0.381 mm, the proportion of head width to body length is 1 : 3.8 and the length of the antenna is 0.43 mm. This stage lasts for 13 days.

After five instars the insect becomes sexually mature, but continues to grow until it attains the maximum size of 1.3 mm. The maximum head width of an adult is 0.43 mm. The total life under laboratory conditions is 75 - 87 days. It takes 50 - 55 days for completing its life-cycle.

EFFECT OF SOIL TYPE UPON OVIPOSITION

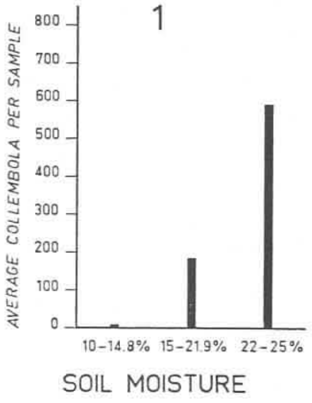
Four types of soil were tested in small culture jars. Twenty full grown individuals of *Onychiurus bhattii* Yosii, selected at random, were liberated in each jar. Proper moisture and food was also supplied to the insects. After 15 days the cultures were washed and the eggs were sorted out under a binocular microscope. Two replicates of this test were made. The following table shows the mechanical structure of the soils and the number of eggs laid in each case.

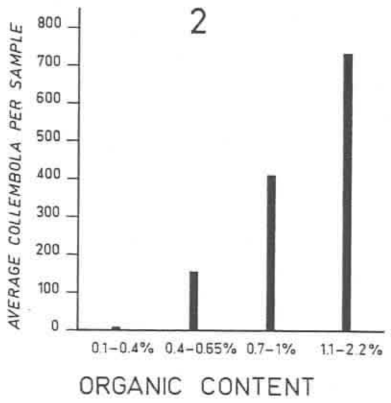
TABLE VII

Number of eggs laid in different types of soil

Soil No.	Coarse sand (Percentage)	Fine sand (Percentage)	Silt (Percentage)	Clay (Percentage)	Number of eggs laid
I	0.5	15.5	57.5	25.5	557
II	1	9	40	48.5	192
III	0.5	36.5	40.5	20	296
IV	2	50	42.5	4	95

It be seen that the maximum number of eggs were laid in soil No. I, which contains 57.5 per cent of silt and 25.5 per cent of clay. Fewer eggs were laid in soil No. IV having 50 per cent of fine sand. DAVIDSON (1934) mentions that sandy soils are unfavourable for oviposition of *Sminthurus viridis* Linn. due to a lower water holding capacity.





GRAPH 1. — Showing the average number of Collembola per sample in various percentages of soil moisture.

GRAPH 2. — Showing the average number of Collembola per sample in various percentages of organic content.

EFFECT OF SOIL pH UPON OVIPOSITION

In this experiment five soils with pH values (determined with a pH-meter) of 7.2, 7.5, 8.0, 8.5 and 9.7 were placed in the culture jars. Fifteen adults of *Onychiurus bhattii* Yosii were liberated in each jar. Sufficient moisture and food were supplied. After an interval of fortnight, the soil in culture jars was washed and the eggs were counted under a binocular microscope. The following table shows the pH values of the soil and number of the eggs laid in each case.

TABLE VIII

Number of eggs laid in soils of different pH values

Soil No.	Soil pH	Number of eggs laid
I	7.2	295
II	7.5	215
III	8.0	79
IV	8.5	Nil
V	9.7	Nil

The maximum number of eggs were laid in the soil with pH value of 7.2, while no eggs were found in the soil with pH values of 8.5 and 9.7. It has been observed that all the individuals survived in almost all cases except in the soil with pH of 9.7 in which a few were found dead.

MACLAGAN (1932) found that *Sminthurus viridis* Linn. laid a maximum number of eggs in the soil having a pH of 6.5, while DAVIDSON (1934) mentions that a soil with a pH of 5.5 - 7.0 is best for oviposition for this species.

FOOD AND FEEDING HABITS

The Collembola feed upon a variety of food. It has been observed (CASSAGNAU, 1961) that under laboratory conditions the Collembola may feed upon any food which is available, but under natural conditions they exercise selection. CHRISTIANSEN (1964) mentions that most of the soil forms feed upon decayed and decaying plant material, fungi and bacteria. MILES (1947) reports that springtails eat lichens, moulds and algae, and mycelium and spores have also been found in their stomachs. Some of the smaller Collembola feed upon the faeces of the Arthropods (PALISSA, 1954-55). KNIGHT (1964) correlated the distribution of Collembola mainly with the distribution of fungi.

Soil forms have also been reported to cause serious damage to plant roots and seedlings (DAVIES, 1926 ; BROWN, 1954 ; WINNER, 1959 and EDWARDS, 1962). *Sminthurus viridis* is a phytophagous species and feeds upon a number of plants including lucerne, clover, beans, sugar-beat, potatoes, oats, barley and grasses (DAVIES, 1928).

CASSAGNAU (1961) and MACNAMARA (1924) report the following carnivorous species; members of genus *Friesea* feed upon the Rotifers, Protura and Tardigrades, and *Isotoma grandiceps* upon the Collembola. MILES (1947) records *Anurida maritima* as a carnivorous species feeding upon the soft tissues of dead molluscs, fish and crustacea.

Recently CHRISTIANSEN (1964), while reviewing the previous literature on the food of Collembola, mentions the great diversity of views regarding the food of Collembola under natural conditions. He has classified these insects into ten groups according to their food requirements which are as follows: « (a) fungal hyphae, bacteria, dead or decaying plants, and grass; (b) pollen grains, unicellular algae, and spores; (c) pollen grains, spores, and live plant material; (d) decaying and dead plants; (e) bacteria and decaying plants; (f) bacteria; (g) fungal hyphae and bacteria; (h) live animals; (i) dead animal material; (j) fungal juices. »

Most of the species, under observations during the present study, feed upon decayed and decaying plant materials. Under laboratory conditions some species have been successfully reared upon freshly fallen leaves of plants. It has been observed that certain species prefer to eat leaves of certain plants, for instance *Onychiurus bhattii* Yosii, *Ceratophysella communie* Folsom and *Sminthurinus mime* Börner showed preference for the leaves of *Trifolium* and *Sesbania aegyptica.* Leaves with hard surface are not readily taken. Species like *Salina multiseta* Yosii et Ashraf and *Seira* *indra* (Imms) have also been seen feeding upon fungi. *C. communis* and *S. mime* were found in large numbers feeding upon damaged fruits of guava.

Cyphoderodes punjabicus Yosii *et* Ashraf has been collected from the fungus combs and chambers of the colony of termites. This species feeds upon regurgitated food of the termites.

The Collembola start eating (or nibling at or cut through) the lower or upper epidermis of the leaves and make small holes and thus reach the mesophyll tissues which they eat. It has been observed that only the veins of leaves and ragged portions of the epidermis are left behind.

NATURAL ENEMIES

In order to determine the natural enemies of the Collembola, a series of laboratory tests were conducted by transferring possible predators among the soil insects to petri dishes with all stages of living *Onychiurus bhattii* Yosii. As a result of this investigation the adults of the following species of insects and arachnids were found to prey on the Collembola.

DERMAPTERA	Size *(Length × Width)*
1. *Anisolabis annulipes* (Lucas)	10.5 × 2 mm
2. *Nala lividipes* (Dufour)	10 × 2 mm
3. *Labidura riparia* (Pallas)	15 × 2.5 mm
COLEOPTERA	
4. *Philonthus paederoccles* Mitsch	8 × 1.6 mm
5. *Staphylinus* sp.	13.5 × 2.6 mm
ARACHNIDA (Spiders)	
6. *Lycosa* sp.	6 × 2 mm
7. *Pardosa sumatrana* (Thorell)	6.5 × 2.9 mm
8. *Pardosa birmanica* Simon	7 × 2.5 mm

In order to judge the efficiency of these predators *Labidura riparia, Anisolabis annulipes* and *Pardosa birmanica* were placed in a petri dish, lined with filter paper which was kept continually moist, and some food (dead plant material and some algae taken from the place of collection) was also

TABLE IX

Predators of *Onychiurus bhattii* **Yosii**

Predator	Period in captivity	Days in captivity	Number of *O. bhatti* eaten	Average No. eaten/day
L. riparia	28-6-63 to 6-8-63	40	132	3.3
A. annulipes	28-6-63 to 6-8-63	40	121	3
P. birmanica	28-6-63 to 6-8-63	40	80	2

provided in the dish. Both the adults and young of *O. bhattii* were supplied to the predator daily or on alternate days. The total number of Collembola eaten during the period of captivity by the specific predator were counted.

Thus during 40 days the total number of Collembola eaten by *L. riparia* were 132, by *A. annulipes* 121 and by *P. birmanica* 80.

MACLAGAN (1932) mentions that *Forficula auricularia* is the most voracious of all the predators of *Sminthurus*. One female can eat six *Sminthurus* daily, while the male can consume 5.7. Among the spider predators, he gives priority to *Erigone* sp. which can consume 2.4 *Sminthurus* daily.

During the period of this investigation no parasite of egg, juvenile or adult Collembola was observed. PHILLIPS (1946) records the nematode parasites from the mesothorax of *Neanura grassei* (Denis).

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